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Editorial

Pre-attentive and attentive mechanisms in vision. Perceptual organization and dysfunction

The 2-day Research Conferences preceding ARVO, sponsored by Vision Research, Elsevier and ARVO, are designed to provide updates on major areas of interest to the vision research community. The goal of the third conference, which took place 7–8 May 1999, was to convene a multi-disciplinary audience interested in pre-attentive and attentive mechanisms in Vision, which is an important distinction in perceptual organization. Pre-attentive mechanisms transform the visual input rapidly and in parallel, and parse the image into coherent parts. One of these parts may pop-out and trigger a behavioral response. However, in many cases pre-attentive mechanisms are not sufficient, and visual attention needs to be invoked. Attention can only be focussed on one or a few parts of the scene. Neuropsychological and psychophysical studies provide evidence for the distinction between pre-attentive and attentive mechanisms. Another distinction is between processing that leads to visual awareness, and processing that does not. Although attention promotes the entrance of visual stimuli into subjective awareness, the precise relation between visual awareness and attentive processing is not yet clear. Recently, research has started to focus on the difference between visual processing that gives rise to awareness and processing that does not. In a combined effort (neuro)psychologists and physiologists have started to unravel the mechanisms underlying awareness, attention and perceptual organization.

This volume of Vision Research is devoted to this symposium and contains 28 papers, divided over six sections.

1. Pre-attentive mechanisms in perceptual organization

In perceptual organization, elements that make up a scene are combined into coherent objects according to the Gestalt rules. Perceptual organization according to these rules occurs rapidly and in parallel, and is therefore considered to be independent of attentive mechanisms.

However, recent evidence suggests that even certain complex feature conjunctions, which were traditionally believed to require attention, may also be processed in parallel, for example, after prolonged training. On the otherhand pre-attentive segregation may not occur in cases in which attention is focussed elsewhere. This section aims to establish the characteristics of pre-attentive mechanisms and their limits. The paper by Nothdurft studies the additivity of saliency effects in different stimulus dimensions and concludes that they are often less salient than predicted from the sum of the individual saliency components. The second paper by Carrasco et al. reports the benefits of spatial covert attention on contrast sensitivity when a Gabor patch is presented without a local post-mask. Their results support the signal enhancement model of attention. The third paper by Gilbert et al. reviews the neutral substrate underlying contour integration and surface segmentation in early visual processing (V1). They show that the contextual influences are subject to perceptual learning and that they are strongly modulated by visuospatial attention. They conclude that V1 is a dynamic and active processor, subject to top-down influences.

2. Attentive mechanisms in visual perception

Typical natural scenes are composed of a multitude of visual objects. The visual system can select one or a few of these objects for a more thorough analysis. When this selection operation cannot be based on elementary feature differences, it has to be guided by visual attention. Also, the various features that belong to a single object, like motion, color and shape, need to be integrated, or else these features may be misperceived in erroneous combinations. As soon as attention is directed to a visual object, its features are hypothesized to be bound together into a coherent object representation.

Neurons in early visual areas, as well as in areas of the inferotemporal and parietal cortex, become more

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active when visual attention is directed to the stimulus they respond to. The question is what factors determine which areas and neurons are involved. In this section, consisting of five papers, new psychophysical and physiological findings on attentive selection will be presented. The first paper by Palmer et al. is a theoretical review from a psychophysical perspective of the effects of attention in visual search. They conclude that low threshold theories can account for simple visual search without invoking mechanisms such as limited capacity or serial processing. The second paper by Dosher and Lu deals with the mechanisms of spatial attention underlying precue validity effects. They found that external noise exclusion is the primary mechanism of cue validity effects, with large effects in high noise displays, and that precues allow observers to reduce noise and to focus on the target in the precued location. Also Baidussi and Burr study two tasks, identification and location of a tilted target in the presence of noise. They found that subjects could identify the direction of the target tilt at thresholds well below those necessary to locate its position. Their data suggests perceptual summation of target and distractors and that the visual system can choose between high performance over a limited area or poor performance over a much wider area. In the next paper Koválcs reviews her work on the development of perceptual organization in man. Local analysis of elemental visual features is shown to develop earlier than contextual effects from their surrounding. Her data indicates that long-range neuronal connectivity in the posterior pole of the brain and in the central visual pathway is not fully developed in young children. In the last paper Motter and Holsapple analyze target detection in monkey as a function of target eccentricity. They conclude that the passive constraint of cortical magnification in combination with an active selection for a stimulus attribute, in their study color, sets the spatial framework for the detection of a target.

3. Role of attention in perceptual organization

Many of the original theories on visual attention proposed that attention is a predominantly spatial phenomenon, best described as a spotlight, or zoom lens. However, human observers are quite able to direct attention to one of a number of spatially overlapping objects. In these situations, the distribution of visual attention is guided by 'preattentive' perceptual grouping criteria, which determine the regions of the image that are grouped together, thus defining objects. This section focuses on object based attention and thereby touches on the relationship between attentive and preattentive mechanisms.

Neurophysiological correlates of spatial attention have often been found, but only recently neurophysiological experiments provide a neuronal correlate of object-based attention. This section compares neurophysiological and psychophysical data to elucidate the role of object based attention in perceptual organization. The first paper by Davis et al. questions past demonstrations that one object may be more easily attended than two objects and concludes that reported difficulties in attending two objects may be due to attention across the entire spatial extent of objects when judging their parts rather than a fixed inability to process more than one object at a time. The paper by Kimchi elaborates further on this point and shows that disconnected line segments are more rapidly organized into configurations provided the presence of collinearity and/or closure. In the next paper, Ahissar and Hochstein show that when the detection of a target element with an odd orientation imbedded in an array of elements with uniform orientation, becomes more difficult, the window of attention shrinks and learning becomes more localized. They conclude that the spread of spatial attention and thus of learning is determined by the integrated effects of target distribution and task difficulty. Shioiri et al. show in their paper that the judgements of interpolated motion for attentive tracking and apparent motion are similar to those for continuous motion in both the perceived path and the precision of the judgements. Their results suggest a specialized motion analysis which provides an accurate model of the interpolated motion path. Rich and Gillam in their paper study the effect of perceptual grouping on the ability to detect changes and found that it is easier to detect changes in stimuli that are strongly grouped. Furthermore they found that changes in location are more difficult to detect than changes in identity, in their case color. They hypothesize that swap-type changes between two existing colors are harder to detect because they require attention to a conjunction of position and color. Roelfserna et al. attempt to delineate how elemental operations like visual search, texture segregation and contour grouping are implemented in the visual brain. It is suggested that such elemental operations can be sequenced in order to solve complex visual tasks. They argue that firing rate modulations effectuate grouping of neuronal responses into coherent object representations and that they can transfer information from one elemental operator to the next, yielding flexibility in the sequencing of operations. Finally they hypothesize that attention is the psychological correlate of a collection of elemental operations which are all associated with the spread of rate enhancement among visual cortical neurons. In the last paper, Grossberg and Raizada simulate the LGN, V1 and V2 as a network of interacting neurons. These simulations show how attention can selectively propagate along an object grouping and protect it from competitive masking, and how contextual stimuli can enhance or suppress groupings in a contrast-sensitive manner.

4. Attentive vision and eye movements

A key issue in attention research concerns the extent to which novel stimuli capture attention and the eyes. Two parallel pathways seem to be involved in saccade generation: a subcortical one via the superior colliculus, that is responsible for generating reflexive, orienting saccades, and a cortical one, headed by the frontal eye fields, for generating voluntary, goal directed saccades. It seems most likely that there are multiple influences on attentional capture, rather than a single mechanism that operates under all circumstances.

The posterior parietal cortex (PPC) has activity related to sensory stimulation, attention and intentions to make saccades and reaches. Snyder et al. review studies showing that in monkey a large component of neural activity in the lateral intraparietal area (LIP), which receives inputs largely from extrastriate cortex, is related to planning saccades, and activity in a nearby parietal reach region (PPR) to reaches. They conclude that LIP activity is greater when monkeys plan saccades and PRR activity is greater when monkeys plan reaches. Their results suggest that activity in PPC reflects both target and movement selection, which is consistent with the notion of PPC playing a role in visual motor transformations for spatially guided behavior.

Irwin et al. in their paper investigate whether attentional (and oculomoter) capture occurs only when abrupt onsets, which define new objects, are used as distractors in a visual search task, or whether other salient stimuli also capture attention and the eyes, even when they do not constitute new objects. They show that both abrupt onsets and luminance increments elicit reflexive, involuntary saccades (as well as covert attention shifts), whereas transient color changes do not.

Since neurons in the superior colliculus do not discriminate color, color distractors should be incapable of eliciting involuntary, reflexive saccades, as found in this paper. Since activity in parietal cortex is associated with attention as well as with vision, the question arises as to whether the 'visual responses' of parietal neurons are visual or attentional. Gottlieb et al. in their paper assess the difference between responses to stimuli that enter the receptive field by virtue of a saccade, and responses to stimuli that appear de novo in the receptive field. They found that neurons respond better to recently flashed stimuli that enter their receptive fields by virtue of saccades than to stable, behaviorally irrelevant stimuli brought into their receptive fields by saccades. Furthermore these neurons respond transiently to abrupt motion onsets, but have no directional selectivity. They conclude that LIP is important for the attentional selection of a saccade target rather than for the intention to generate the saccade.

5. Attention and visual awareness

The aspect of visual information processing that is most familiar to us is visual awareness. In fact, we do hardly realize that much of the information that fails on our retinas is either lost, or transformed into some motor output. A dissociation between 'automatic' visual responses and visual awareness is most strongly expressed in blindsight patients, but is also observed in normal observers. Recent findings with respect to change blindness point to an important role for attention in visual awareness. The data suggest that we are not aware of objects in the scene to which we do not pay attention.

This section explores the relation between attention and visual awareness. Are we aware of visual input without calling attentional resources into play and what can neurophysiological experiments tell us about visual awareness and its relation to attention?

In the first paper, Rensink surveys the use of change perception in exploring three different aspects of vision: seeing, sensing and scrutinizing. To explain why change blindness can be easily induced in experiments but not in everyday life, Rensink proposes that in perception object representations do not accumulate but are formed as needed, and that both attentional and non-attentional streams are involved. Sensing is the ability of observers to detect changes without visually experiencing them. He proposes that both are due to the operation of a non attentional visual stream. In scrutinizing items, the attentional mechanisms come in the picture. Rensink shows that the limits on visual search for change provide a powerful means to map out the attentional mechanisms involved.

In the second paper, Itti and Koch present a computer implementation of a preattentive selection mechanism based on the architecture of the primate visual system. They address the problem how information from different modalities — in this study from 42 maps encoding intensity, orientation and color in a center-surround fashion at a number of spatial scales — can be combined into a single saliency map. Their algorithm qualitatively reproduces human performance on a number of classical search experiments.

The remaining two papers search for neural correlates of visual awareness in awake monkey; the first one by Lamme et al. in the primary visual cortex, and the second one by Thompson and Schall in the frontal eye field (FEF), an area located in the prefrontal cortex.

Both papers describe late onset modulations in neuronal activity which are related to whether stimuli are perceived or not. The combination of related findings in V1 and frontal cortex provides evidence for models of visual awareness that are based on a general 'state' of activity that involves many areas of the brain simultaneously, and that is achieved by recurrent feedforward–feedback connections.

6. Dysfunction of perceptual organization

Lesions in human patients and monkeys have revealed a number of syndromes that have guided thinking about the neural substrate of preattentive and attentive mechanisms, and also about the correlates of visual awareness. Some lesions in particular regions of the visual cortex are associated with disorders of perceptual grouping. Other patients exhibit a disturbance in redirecting visual attention from one perceptual object to the next. Moreover, lesion studies have revealed remarkable dissociations between visual awareness and the transformations required for the visual guidance of action. This section discusses the implications of lesion studies for our thinking on visual cortical processing.

The first paper by Altpeter et al. employs the fact that by an 'effort of will', one can pay attention to a location in the visual field without looking at it directly. This sustained attention facilitates recognition of targets at that location. They found that this willful deployment of sustained attention is easier on the horizontal than on the vertical meridian. So the technique of eccentric viewing by which patients with maculopathies may learn to read again, has to take topographic features of sustained attention into account.

The next paper by Peterson et al. presents two case studies on brain damaged subjects whose conscious object recognition was either severely impaired (visual agnosic) or relatively spared. In these two subjects they investigated whether conscious object recognition is necessary or sufficient for effects of object memories in figure assignment. They found that the subject with relatively spared conscious object recognition was impaired in applying object memories in figure assignment whereas the opposite result was obtained in the subject without conscious object recognition. Thus conscious object recognition is neither necessary nor sufficient in figure assignment.

The third paper by Humphreys et al. reports data from a patient with bilateral parietal lesions, who manifests left-side visual extinction along with many illusory conjunctions when asked to discriminate both surface and form information. Their results support a two-stage account of visual binding: form elements are first bound together locally into shapes, and next shapes are integrated with surface details. This second stage is impaired in this patient.

The next paper by Haffenden and Goodale shows that pictorial displays can exert opposite effects on perceptual size judgements and grip scaling. The reason is that the neural mechanisms mediating visuomotor control are separate from those mediating phenomenological perception. Vision for perception and vision for action can be mapped into two pathways: respectively the ventral and the dorsal stream. This paper presents a behavioral dissociation between the outputs of these two streams in normal observers by presenting pictorial illusions that change the perceived size of targets that have to be picked up. Grip aperture proved to be correlated with the real size of the target and not with the perceived (illusory) size.

The last two papers in this section by Schiller and Chou examine the effects of frontal lesions in the frontal and medial fields in rhesus monkey on visual guided eye movements. They show that lesions of the frontal eye fields produce major deficits in the execution of saccadic eye movements to sequentially presented targets that did not recover even after one year. On the other hand medial eye fields produce much smaller and shorter-duration-deficits on this task. None of the lesions produced deficits in executing combined saccadic and pursuit eye movements to moving targets. Since lesions in both areas produced similar deficits as single frontal aye field lesions, their results suggest that the frontal eye field area plays a central role in the execution of sequences of eye-movements, in temporal processing and in target selection. The latter two are the topics of their second paper.

7. Concluding remarks

This 2 day symposium which took place 7–8 May 1999 as an official satellite meeting of ARVO, was attended by 369 delegates. They participated in stimulating discussions and observed the presentation of 25 single stream papers from the platform and 84 papers in poster format. I want to thank the speakers and the authors of other relevant submitted papers for finalizing their manuscripts in time, so that this volume of Vision Research containing 28 papers will be available before ARVO 2000 when the fourth symposium in this series will be held on Functional Brain Imaging in Vision at 28–29 April 2000.

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